PRINCETON PLASMA PHYSICS LABORATORY THEORY PROGRAM PLANS

BUDGET PLANNING MEETING

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Germantown, Maryland

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PPPL THEORY PROGRAM
Supports Goals Emphasized by FESAC

- **Advance *fundamental understanding of plasmas* through analytical and numerical studies**
- **Help develop/optimize *innovative confinement configurations* and interpret initial experimental results with advanced theory/computational tools**
- **Collaborate on the analysis and planning of experiments for *high-performance plasmas***
- **Support the development of *enabling technologies***
- **Provide new theory/computational tools to aid development of efficient ion beam (*IFE*) systems**

PPPL THEORY PROGRAM
Has Well-Defined Target & Approach

- ***TARGET*** **--- RELIABLE PREDICTIONS OF PROPERTIES OF FUSION PLASMAS**
  - **Scientific Challenge*:*** ***Understanding*** **of complex physics phenomena impacting plasma performance &** ***Integration*** **of such knowledge into predictive models that prove superior to empirical scaling**

- ***APPROACH*:**
  - **Planning and interpretation of experiments on existing facilities; design of new facilities; cross-cuts to other areas of science** ***(shorter-term impact)***
  - **Develop innovative new tools for analyzing wider range of phenomena with greater accuracy** ***(medium-term impact)***
  - **Generate seminal concepts advancing basic physics as well as confinement systems** ***(longer-term impact)***

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PPPL THEORY PROGRAM
Emphasizes Accountability & Partnerships in Advancing Plasma Science

- ***ACCOUNTABILITY***
  - **Strong track record for producing seminal theories & reliable codes**
  - **Well-motivated goals with deliverables & associated time-lines**
  - **Steering Committee to enhance productivity & communication**
    - **IFE & Non-MFE Plasma Science (Davidson); MHD (Jardin); Transport (Hahm); Waves/Energetic Particles (Cheng); Non-Axisym. Systems (Reiman); Laser-Plasma Interactions (Valeo)**

- ***PARTNERSHIPS***
  - **With theorists and theory groups, nationally & internationally**
  - **With experimentalists and experimental groups, nationally & internationally**
  - **With advanced scientific computing community**
  - **With technology development**

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PPPL THEORY PROGRAM
Addresses a Wide Range of Scientific Areas

- **Scientific Objectives have been identified together with expected deliverables over next two years**
  - **Consistent with Scientific Challenges highlighted in *FESAC Report on Priorities and Balance (8/99)***
- **Advanced Scientific Computing plays key role in all areas of research:**
  - **MACROSCOPIC STABILITY**
  - **TURBULENCE & TRANSPORT**
  - **WAVE-PARTICLE INTERACTIONS (Energetic Particles)**
  - **MULTI-PHASE INTERFACES (Boundary Physics)**
  - **NON-FUSION PLASMA SCIENCE (IFE)**
- **Illustrative Roadmaps (examples of targeted deliverables & associated time-lines)**

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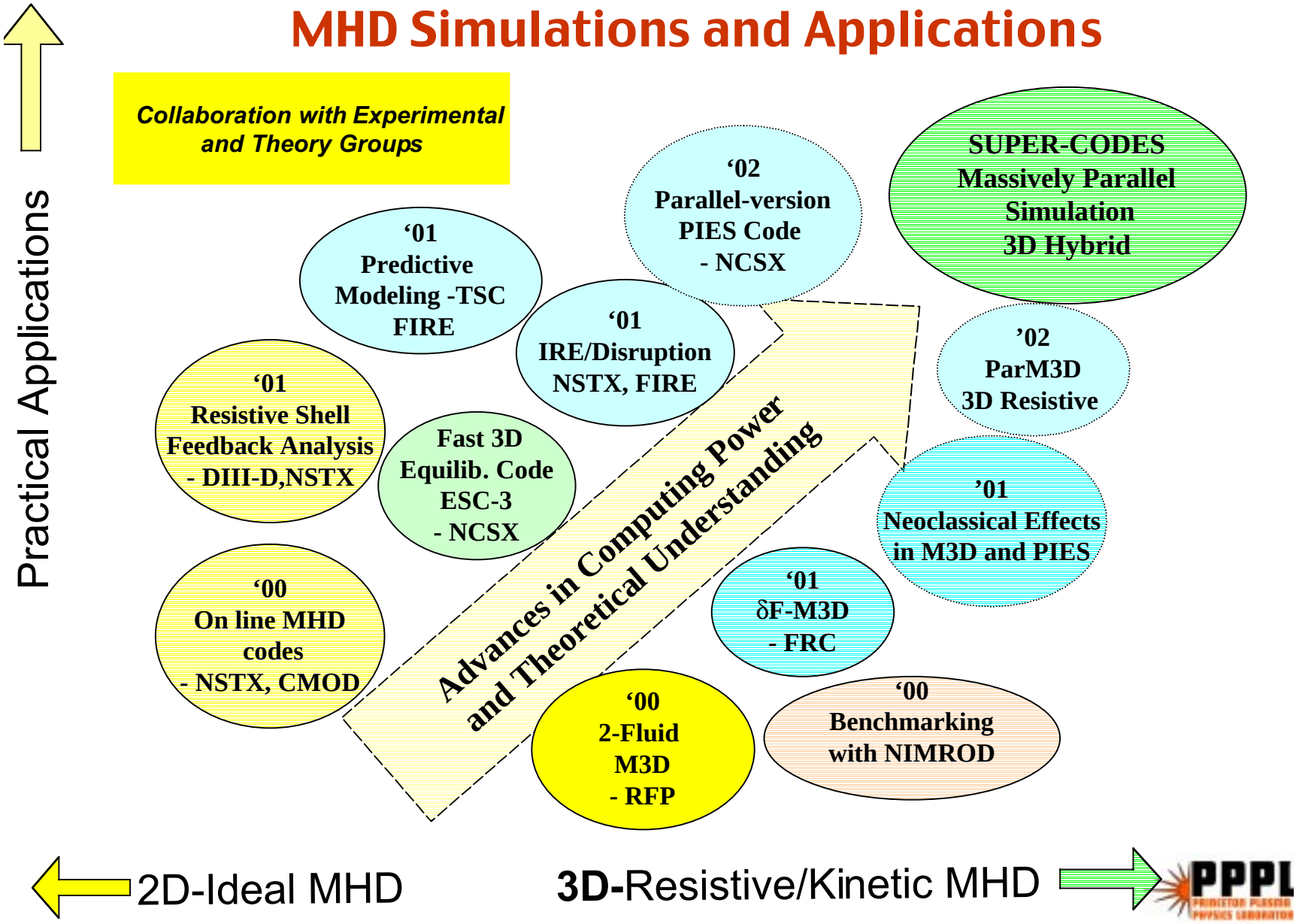
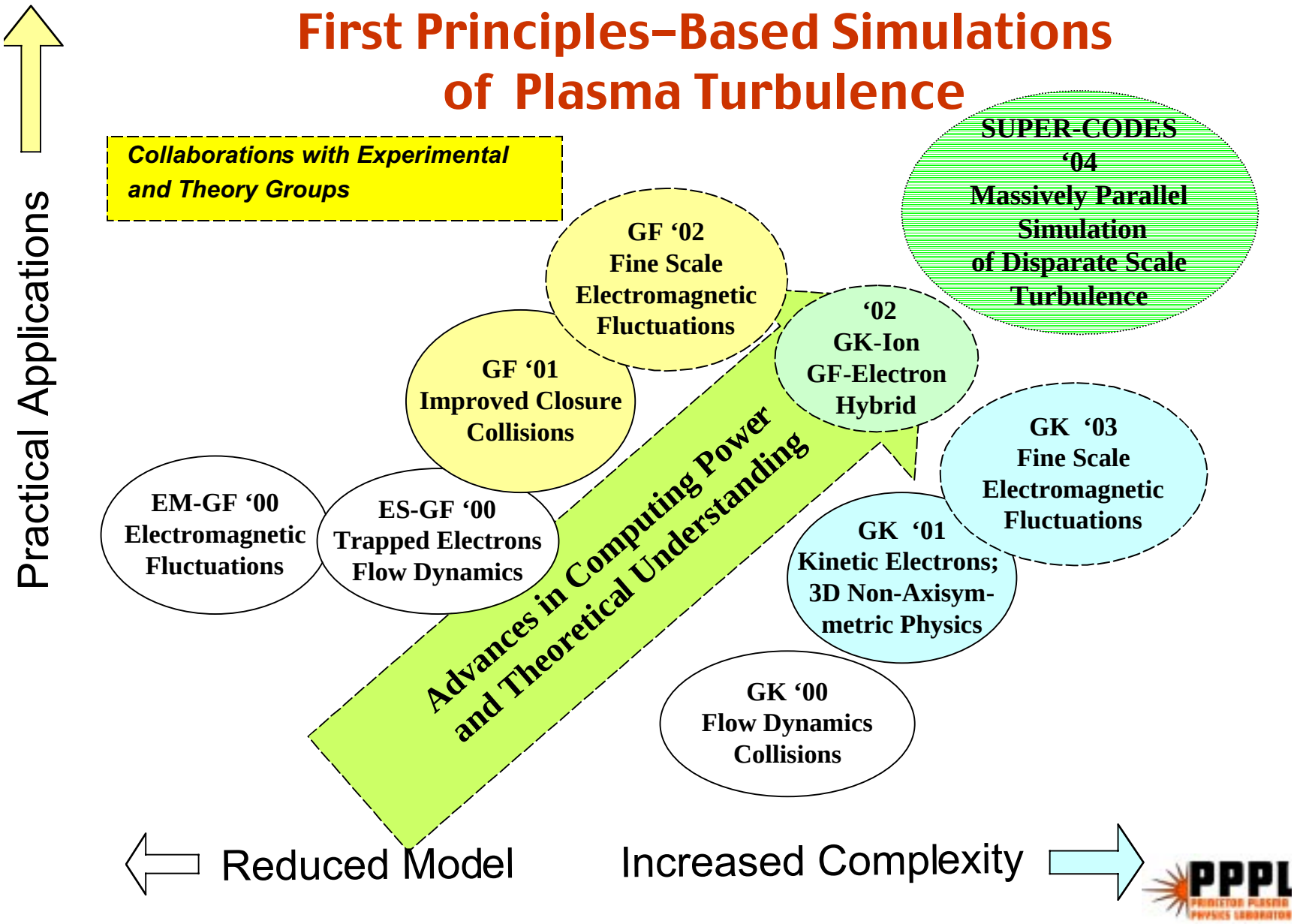
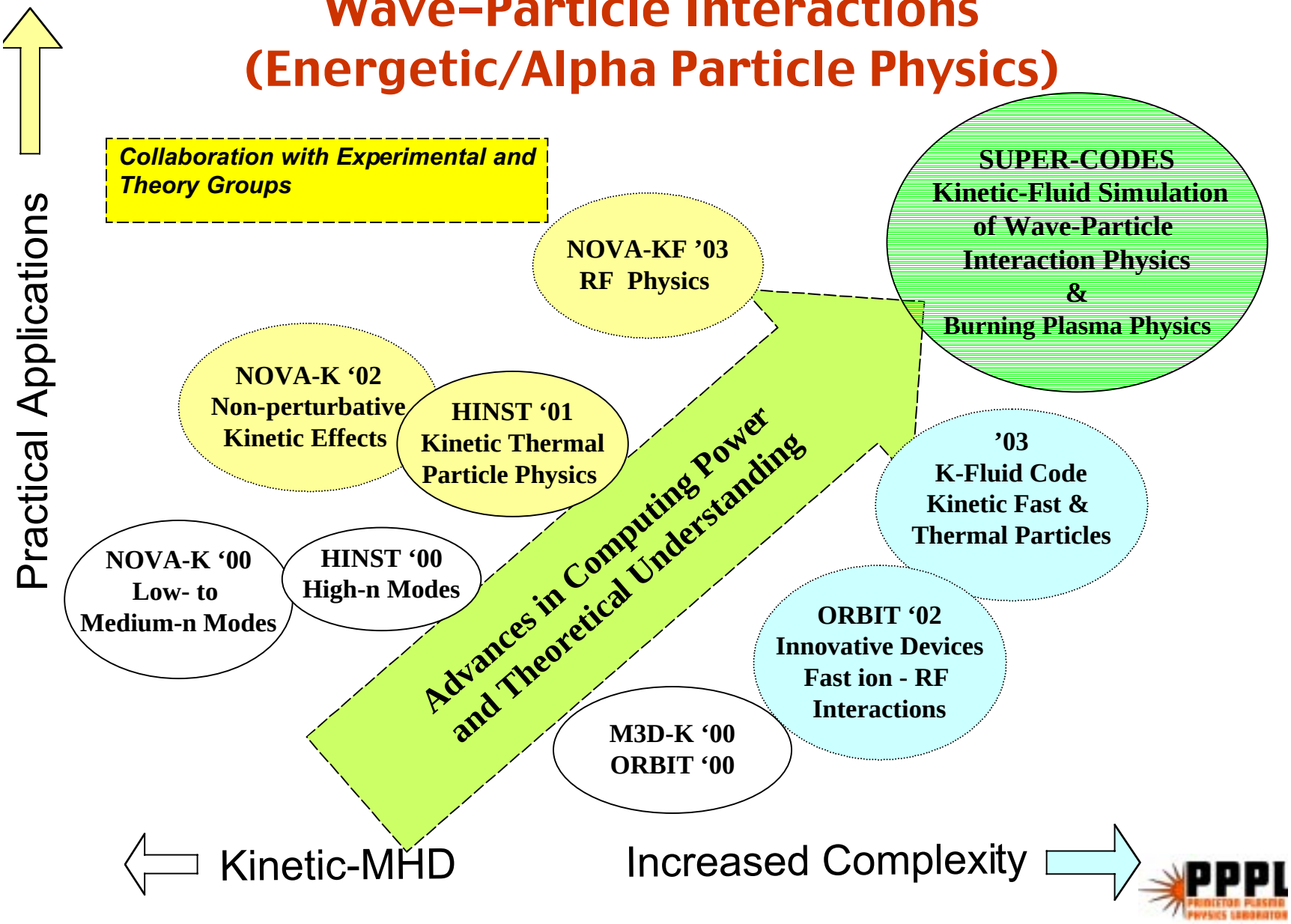
MHD Simulations and Applications



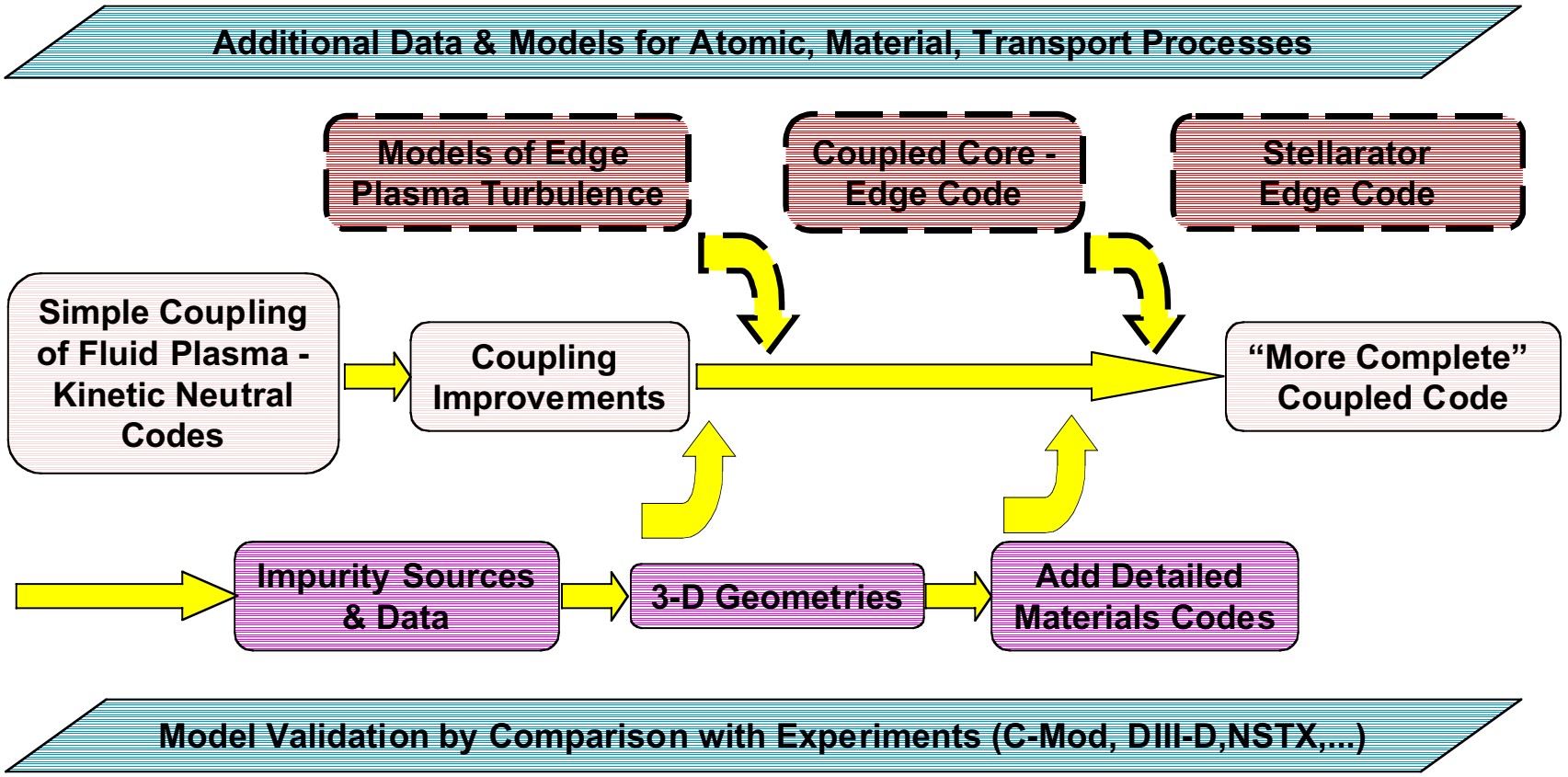
First Principles–Based Simulations of Plasma Turbulence



Wave–Particle Interactions (Energetic/Alpha Particle Physics)



Predictive Capabilities for Multi-Phase Interfaces



1999	2000	2001	2002	2003	2004

Neutral Code

Coupled Plasma-Neutral Codes

Input from Community

External Collaborations

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PPPL IFE THEORY RESEARCH

- PPPL Theory plays key role in **Heavy Ion Fusion Virtual National Laboratory** (HIF-VNL) together with LBNL and LLNL.
  - lead positions in the HIF-VNL including Deputy Director (R. Davidson) and Deputy Head of Theory and Modeling (W. Lee)

- Technical Focus of PPPL Collaboration includes:
  - Advanced analytical and numerical modeling of intense beam propagation and beam-plasma interaction.
  - Development and application of RF techniques for preionized plasma formation.
  - Feasibility study of negative-ion-based heavy ion neutral beam driver.

Some Examples of PPPL Theory Collaborations

- High-impact results from collaborative applications of state-of-art global GK code to zonal flow turbulence suppression studies [P. Diamond (***UCSD***), L. Chen (***UCI***)]
- Collaborative development & applications of 3D nonlinear resistive MHD code (M3D) [H. Strauss (***NYU***), L. Sugyama (***MIT***)]
- Collaborative development of RWM analysis capability for DIII-D [M. Chance – @ ***GA*** for one year]
- Highly productive collaborations on international facilities (***JET, JT60U, LHD, ASDEX,*** ..) addressing Turbulent Transport (Rewoldt, Beer); MHD (Manickam, Monticello); Energetic Particles (Cheng, Gorelenkov, White); Boundary Physics (Stotler)

PPPL THEORY PROGRAM
Has Strong Ties to Non-Fusion Plasma Science and to Academic Community

- **NON-MFE RESEARCH** **including:** ***Space and Solar Physics, Laser-Plasma Systems, …..***
- **INDUSTRIAL APPLICATIONS** **including:** ***Plasma Display Panels, Plasma Thrusters, Plasma Processing, Textile Studies, ….***
- **EDUCATION** **including:** ***major Graduate Program/Postdocs/Visiting Scientists*** **-- impact of distinguished graduates/post-docs on community**
  - » **Linkages with Princeton U. Main Campus e.g., Computer Science Dept. partnerships in Visualization & Graduate Education (NSF)**

TARGETS of PPPL THEORY PROGRAM

MHD (examples)

- **Parallelized M3D (parM3D) capable of utilizing large distributed memory MPP's @ NERSC (FY'01-02)**

- **Existence of Magnetic Surfaces in 3D Configurations via systematic applications/comparisons of VMEC, M3D, and PIES (FY'01)**

- **Develop non-inductive current build-up strategies for minimizing pulse length requirements (CMOD, NSTX) via Axisymmetric Modeling of Current Drive and Current Profile Control (FY'01)**

- **Feedback Stabilization Scenario-development for RWM (DIII-D) (FY'01)**

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TARGETS of PPPL THEORY PROGRAM

TRANSPORT (examples)

- **Neoclassical Ion Transport and Bootstrap Current Properties in ST's and 3D (non-axisymmetric) Systems (FY'01)**
- **Object-oriented version of state-of-art codes such as GTC and ORBIT for community collaborations (FY'01)**
- **Applications of linear GK & NL GF simulations with new capabilities (magnetic perturbations & equilibrium ExB shear) to interpretation of fluctuation measurements from JT60U, JET, DIII-D, and C-MOD (FY'01)**
- **Influence of Trapped-Electron Dynamics in global 3D GK analysis of Tokamak Microturbulence (FY'02)**

TARGETS of PPPL THEORY PROGRAM

- *WAVES/ENERGETIC PARTICLES (examples)*
- **Develop and apply Energetic Particle (e.g., TAE) Analysis for experimental planning and interpretation on NSTX, FIRE (FY'01-02)**
- **Assessment of TAE Stability for N-NBI Experiments with plasma flow on JT60U (FY'01)**
- **Analysis of Fishbone Modes & Sawtooth Stabilization on ASDEX (FY'01)**

- *BOUNDARY PHYSICS (examples)*
- **Turbulence imaging for SOL studies on NSTX in collaboration with LLNL (FY'01-02)**
- **Application of Coupled DEGAS2-UEDGE to liquid lithium experiments on CDX-U (FY'01)**

Opportunities in Advanced Scientific Computing

- In response to OFES, PPPL has played a lead role in successfully establishing the ***Plasma Science Advanced Computing Initiative (PSACI)***
  - **Plasma Science Advanced Computing White Paper very well received by DOE Headquarters**
  - **Pilot Programs in Turbulent Transport and MHD Simulations received excellent peer reviews & were launched in FY'00**
  - **Active Program Advisory Committee (with distinguished members from outside & within FES) have provided excellent advice/guidance**
- New DOE Office of Science Initiative for ***"Scientific Discovery through Advanced Computing"*** ***has replaced SSI*** **----** FES has excellent opportunity to be prominent member of this broader scientific portfolio with access to significant new resources in SDAC program

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PPPL Theory Department Budget ($M)

	FY2000	FY2001		FY2002	
		Baseline	Incr.	Baseline	Incr.
Tokamak Theory	2.32	2.33		2.33	0.24
Alternate Theory	1.61	1.58		1.58	0.09
FRC Theory	0.20		0.20		0.20
Advanced Scientific Computing	1.27	1.07	0.80	1.07	0.80
Computation Physics	0.39	0.39		0.39	
National Transport Code	0.11	0.11		0.11	
Origin 2000 System Computing Support	0.10	0.10		0.10	
Software Standardization and Sharing		0.08		0.08	
Predictive TRANSP			0.13		0.14
Total Theory	5.99	5.66	1.13	5.66	1.47

PPPL Theory Department Budget (Physics FTEs)

	FY2000	FY2001		FY2002	
		Baseline	Incr.	Baseline	Incr.
Tokamak Theory	8.5	7.5		6.6	1.2
Alternate Theory	7.8	7.0		6.3	0.5
FRC Theory	0.3		0.3		0.3
Advanced Scientific Computing	3.3	2.0	2.1	2.0	1.9
Computation Physics	0.3	0.3		0.3	
National Transport Code					
Origin 2000 System Computing Support					
Software Standardization and Sharing					
Predictive TRANSP					
Total Theory	20.2	16.8	2.4	15.2	3.9

PPPL Theory Department Budget (FTEs)

	FY2000	FY2001		FY2002	
		Baseline	Incr.	Baseline	Incr.
Tokamak Theory	15.5	11.5		10.6	1.2
Alternate Theory	7.8	7.0		6.3	0.5
FRC Theory	0.3		0.3		0.3
Advanced Scientific Computing	5.4	3.7	2.4	3.2	2.2
Computation Physics	1.6	1.4		1.2	
National Transport Code	0.5	0.5		0.4	
Origin 2000 System Computing Support	0.4	0.4		0.4	
Software Standardization and Sharing		0.3		0.3	
Predictive TRANSP			0.1		0.1
Total Theory (with some support for CPPPG)	31.5	24.8	2.8	22.4	4.3

CONCLUSIONS

- PPPL Theory Program is key National/International Resource for DOE Fusion Energy Science Program
  - ***highly desired for many external collaborations***

- PPPL Theory Program combines:
  - ***accountable progress*** on many of most important, scientifically challenging problems facing FES research
  - ***strong partnerships*** with universities, laboratories, & industry
  - long-standing ***commitment to academic/educational mission*** of DOE FES Program